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Forestry Research West

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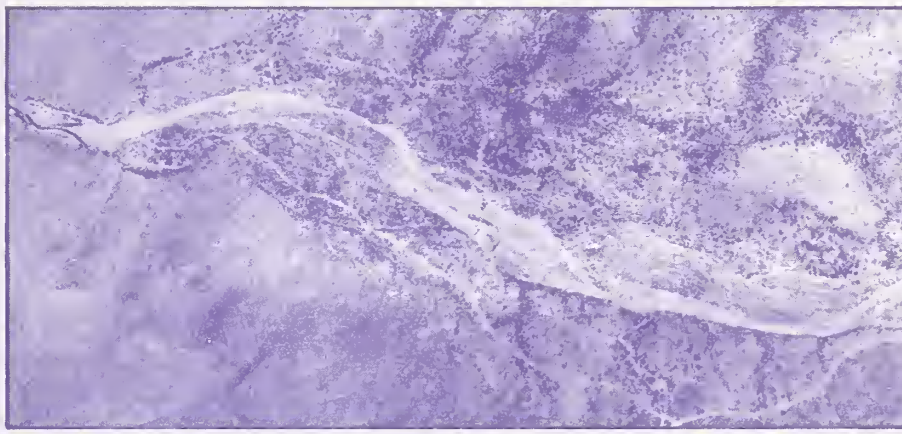

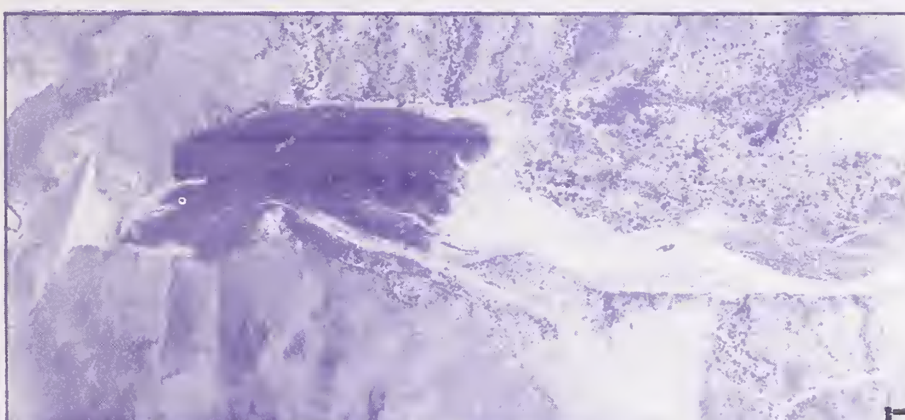

A report for land managers on recent developments in forestry research at the four western Experiment Stations of the Forest Service, U.S. Department of Agriculture.

Forestry Research West

In This Issue

Cover

These aerial photographs show the development of a riparian plant community in central Arizona over a 20-year period. Scientists at the Rocky Mountain Station are developing methods to better manage existing southwestern riparian ecosystems, and create hydrologic regimes more favorable for rehabilitating existing or creating new riparian areas. Read about it beginning on page 12.

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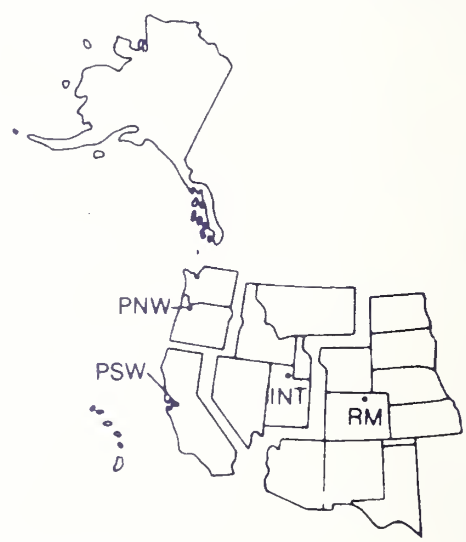
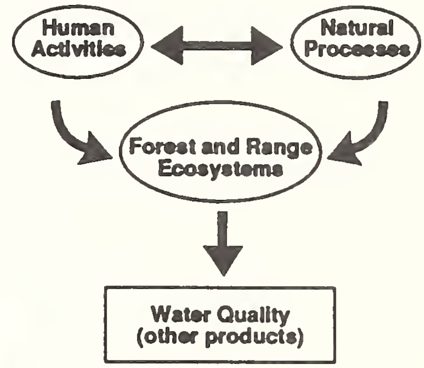


Cumulative effects on an ecosystem

by David Tippets
Intermountain Station

Ninety-eight years after the creation of the National Forests, Forest Service scientists launched high priority research to help the agency perform one of its first charters, producing high-quality water from National Forests and Grasslands. Increasing human activities and a growing demand for resources multiply impacts on the environment and create cumulative effects. "Cumulative effects" or the concern for combined impacts of multiple activities such as logging, road building, mining, and grazing on water quality, set the foundation for this new proactive ecosystem approach to learning about how to preserve water quality.



Husband and wife team, Mike Amacher and Jan Kotuby-Amacher, perform chemical analysis of water and sediment in Birch Creek.

"The farther down you can get on the-food chain, the better you are able to determine some detrimental effect on the ecosystem," Roy Sidle, research hydrologist for the Intermountain Research Station's Logan, Utah laboratory says, explaining that water and soil are the foundation of the food chain and determine the productive potential of all terestial ecosystems. Sidle, the team leader for the Birch Creek cumulative effects research project in the Toiyabe National Forest in central Nevada, suggests that it is important to look beyond the biological components of the ecosystem to the physical and chemical parts.

The Birch Creek project and other Forest Service research across the Nation are integral parts of the Presidential Water Quality Initiative announced in February of 1989. This research also responds to the National Forest Management Act of 1976, which directs the Forest Service to perform cumulative effects analysis on its activities. We will look at the Birch Creek research as an example of how

scientists are learning about the cumulative effects over space and time on water quality from forests and rangelands activities.

Underpinning the system

"If we don't understand the linkages (between the components of the system), we are better off focusing on the physical, chemical, and the most basic biological elements because those are the underpinnings of the system," Sidle explains. "If you focus too high on the food chain, everything can go to hell in a hand basket before you identify a problem."

A contrasting approach would be to focus on the bald eagle, on which human activities can accumulate and kill. The bald eagle is a predator at the top of the food chain that lives mostly on fish that in turn depend on water quality for survival. If you study eagle populations and learn that they are declining, you have strong indications that you have a malfunction lower down in the system, but by the time eagles start to die it may be too late to correct the problem.

Time and space

Harmful effects in the ecosystem can accumulate over both time and space. In the eagle and pesticide example, the pesticides can accumulate and concentrate in space as they flow with spring runoff from farmland into a river. Then the pesticides can accumulate over time in the eagle's body until they reach toxic levels and kill the eagle. The Agricultural Research Service studies the problem of cumulative effects of pesticides.

A mine and a road crossing in a tributary to Birch Creek add additional sediment and chemicals to the main channel.

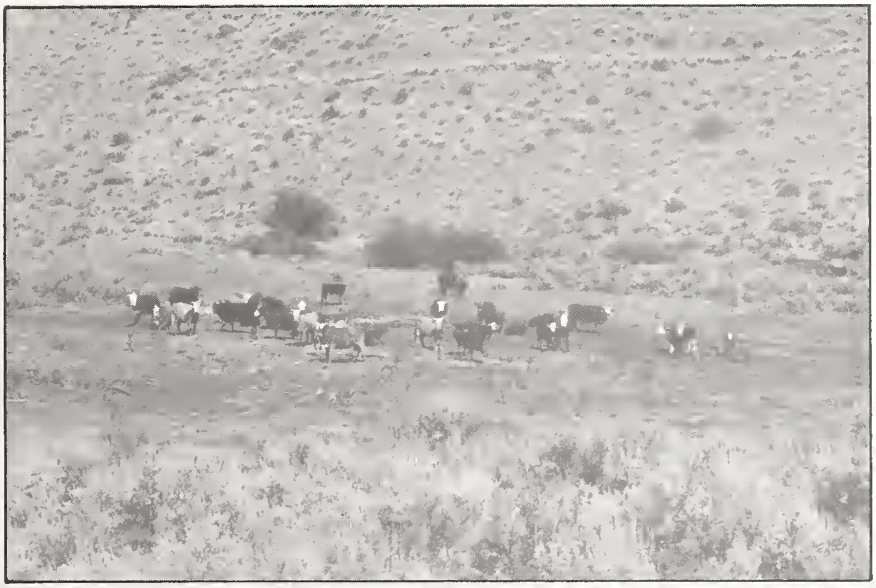
The Forest Service's cumulative effects approach suggests that to save the eagle, or mankind, you are wise to study the chemicals, nutrients, and sediment that determine water quality. And studying the linkage of water quality to the aquatic insects that the trout eats may be more beneficial than studying the fish that the eagle eats because the insects will likely be closer to the source of ecological disorders.

"Fifteen years ago, if we had had a good research program on old growth, the spotted owl would never have become an issue," Sidle suggests. "We would have been in a good position to demonstrate holistic-type management of the old-growth ecosystem."

Proactive research

Studying the driving forces of the ecosystem is proactive management to acquire knowledge so managers can take action to prevent ecological disasters when cracks are first detected in the foundation of the system. Waiting until a large animal's survival is threatened or endangered and then studying that animal is reactive management, and may never result in the information needed to repair the cracks in the foundation.

If one fails to grasp the vital concept of why it is essential to understand the most basic building blocks of our life-support systems, then one would never understand why Sidle and his team look past the small brown trout struggling to survive in Birch Creek.



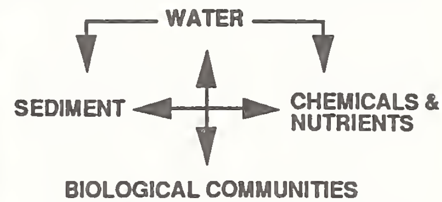
Cattle, congregating in and near the stream channel, add sediment and nutrients to the channel and break down stream banks. Grazing impacts accumulate with natural geomorphic processes and influences from disturbances such as mining and road building.

On one of his first visits to Birch Creek, Sidle saw a small trout fight its way upstream through thick aquatic vegetation. The fish finally tangled in a thick patch of vegetation, stuck there and died.

Sidle's team looks beyond the dead trout, deeper into the stream channel; their research seeks understanding about what natural processes and which human activities combined to grow aquatic vegetation so thick that it clogs the channel.

Natural integration

"The stream channel is the natural integration of most everything going on in the watershed," Sidle explains, describing why his team collects most of its data within or close to the channel. They monitor sediment, chemicals, and nutrients in the channel produced from a variety of sources ranging from the gold mine near the head of the drainage to cattle grazing on the stream banks.



Effects accumulate from different sources. Research reveals that there are fascinating interactions between the plant, animal, and physical components of the ecosystem. Quaking aspen, the largest woody plant that grows in isolated stands along Birch Creek, produces large dead woody material that creates pools in the stream channel. The dead wood and pools trap sediment flowing downstream from the mine and improve fish habitat as long as too much sediment doesn't enter the stream. But cattle eat young aspen sprouts and can prevent aspen stands from regenerating. Over time, scientists will observe and measure the interactions and effects between cattle, aspen, the stream channel, fish, and people.

But many people see time running out for the fish in Birch Creek, and think that it is time to help the fish and not just study the situation. In central Nevada, where the annual precipitation in nearby Austin is only 325 mm, the presence of a reproducing population of trout is of major importance.

Citizen action

Shirley Pollack and John Champion of the Nevada Wildlife Federation watched the fish struggle to survive in Birch Creek and took action. In 1989 Pollack and Champion organized a group of 20 volunteers to help the Toiyabe National Forest build 1 1/2 miles of fence to protect a deeply eroded part of Birch Creek from cattle grazing.

The exclosure allows the cumulative effects research team to learn important information about recovery from the impacts of cattle grazing. Inside the exclosure the team studies (1) physical channel changes, (2) changes in vegetation, (3) changes in the groundwater level, and (4) changes in water chemistry.

Researchers tackle cumulative effects research as a long-term effort, but managers can anticipate useful information before the completion of the study. Sidle hopes his team can work with managers to develop "watershed response variables" and "thresholds of concern," measurable things in the watershed that will act like an early warning system.

Accessory to GIS

By 1992 Sidle hopes to have a cumulative effects sediment model ready for testing on the Birch Creek drainage. Ultimately the model would be a user-friendly accessory to a geographical information system. It will allow managers to play "what if games" with proposed activities—such as "if they double the size of the mine but reclaim exploration roads, what will the impact be on the channel and fish 2 miles down stream."

In a deeply incised section of the stream channel scientists survey and monitor changes in the size and shape of the channel.

The following papers with information from the Birch Creek project and cumulative effects in general have been published or are in process:

Sidle, R.C. 1990. *Overview of cumulative effects concepts and issues*. In: Proc. of 1989 Soc. Am. Foresters Annual Convention. Bethesda, MD: Society of American Foresters: 163–167.

Sidle, R.C. 1990. *Cumulative effects of forest practices on erosion and sedimentation*. In: Proc. of 1989 Soc. Am. Foresters Annual Convention. Bethesda, MD: Society of American Foresters: 108–112.

Sidle, R.C.; Amacher, M.C. 1990. *Effects of mining, grazing, and roads on sediment and water chemistry in Birch Creek, Nevada*. In: Proc. of Watershed Management Symp., Am. Soc. Civil Engrs. (in press).

Halverson, H.G.; Sidle, R.C., 1990. *Cumulative effects of mining on hydrology, water quality, and vegetation*. Proc. of 1990 American Soc. for Surface Mining and Reclamation meetings, Charleston, WV (in press).

Coffman, D.D.; Sidle R.C.; Cutler, D.R., 1989. *Analyzing temporal and spatial characteristics of a management-impacted stream*. Agronomy Abstracts:300.

Sidle, R.C. 1989. *Cumulative effects of vegetation management on slope stability*. Agronomy Abstracts:311.

Sidle, R.C. 1989. *Channel response to cumulative effects of mining and grazing*. EOS Trans. Am. Geophysical Union 70(43):1122 (abstract).

AN INTERDISCIPLINARY TEAM

To understand the complexity of an cumulative effects research project, it helps to know the wide variety of skills and expertise needed for the job. The Birch Creek project's team of players are:

Roy C. Sidle, Research Hydrologist. Roy leads the team and personally investigates channel dynamics, sediment transport, erosion, and recovery of the water table.

Michael C. Amacher, Research Soil Chemist. Mike studies the chemical composition and chemical changes in the water and sediment in Birch Creek.

Janice Kotuby-Amacher. Jan, a post-doctoral research associate with the Plant and Soil Sciences Department at Utah State University, works with her husband Mike on sediment and water chemistry.

Raymond W. Brown, Research Plant Physiologist. Ray studies the uptake and utilization of water from the soil by plants in the stream channel. His emphasis is on the long-term change of water in the soil and how that change impacts the kind and amount of riparian vegetation.

Jeanne C. Chambers, Research Plant Ecologist. Jeanne determines the plant community composition in and near the stream channel, and will monitor changes over time in response to changing channel conditions and grazing.

Walt Mueggler, retired Range Scientist. Walt volunteers on various aspects of the project, including consultation on plant identification and aspen ecology in the riparian areas.

Bryan D. Williams, Senior Technician. Bryan installed and maintains shallow wells known as piezometers that allow monitoring of changes in water that is below ground level. In addition, he assists with almost all other parts of the project.

John Binder, Biological Technician. John measures the frequency and density of riparian vegetation.

Jim Mabe, Buckaroo Range Technician. Jim's time is contributed by the Austin Ranger District to make sure that the cattle exclosure fence is maintained and cattle are kept out of the recovery area. Jim also helps collect data from the piezometers.

Weimin Wu, Ph.D. candidate in Watershed Science at Utah State University. Wu, from the People's Republic of China, is developing a computer model to predict cumulative effects that will be tested in the Birch Creek study.

Darren Coffman, former graduate student in statistics at Utah State University. As part of his masters thesis completed in 1989, Darren developed a model to analyze changes in Birch Creek measured over both time and space.

The Starkey Project: planning for the future

by Judy Hector
Pacific Northwest Station

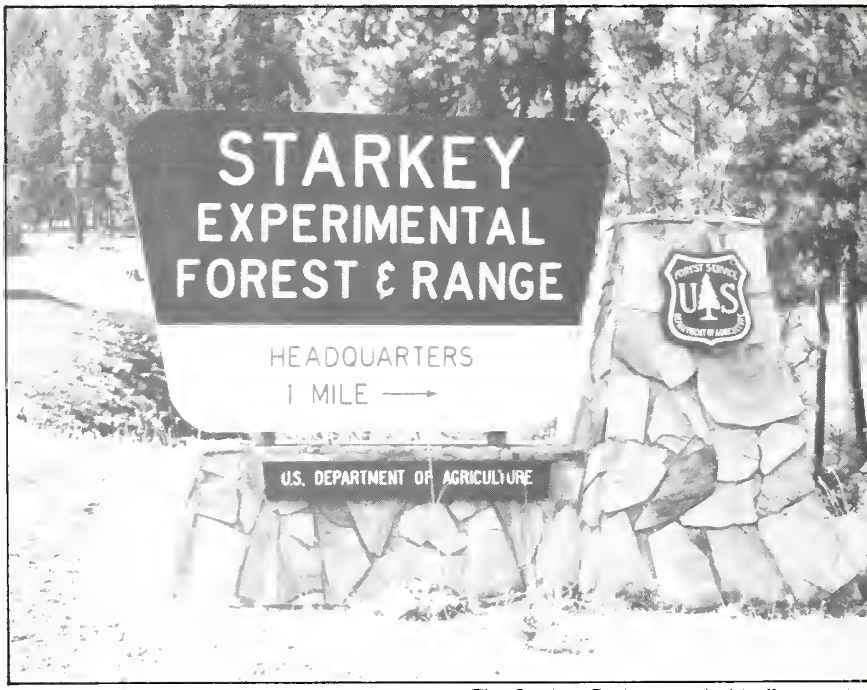
In the folds of the Blue Mountains of eastern Oregon, deer, elk, and cattle graze freely on 25,000 acres of the Starkey Experimental Forest and Range. Here, researchers are simulating intensive forest management to create a view of issues resource managers will need to address in the next decade.

Researchers from the Oregon Department of Fish and Wildlife and the Forest Service are studying the animals to find answers about tradeoffs between objectives for elk and deer and forest activities including intensive timber management, cattle grazing, vehicle traffic, and hunting. The animals are part of the most intensive free-range study ever undertaken to examine how animal populations respond to habitat changes.

The Starkey project is a 10-year, multimillion dollar investment. At stake are hundreds of millions of dollars in local, regional, and national economies and thousands of jobs in the timber, livestock, and recreation industries.

The setting

To begin their studies, researchers needed a population of animals in a large, controlled area where the animals could range freely. In 1987, researchers enclosed 25,000 acres of the Starkey Experimental Forest and Range with deer- and elk-proof fencing to keep deer, elk, and cattle from moving into or out of the research area. This level of control allows direct monitoring of ungulate populations.



The Starkey Project is a bold effort to give natural resource managers information they will need to address future issues.

The fence at Starkey surrounds 40 square miles of gently rolling hills, steep canyons, and perennial streams. The area is large enough to encompass the typical summer range of most deer and elk herds and possesses habitat features representing those found on many National Forests in the Intermountain West. Consequently, results may be applicable to many areas in that region. Within the enclosure, the study area has three parts: 20,500 acres of main study, where most activity takes place; 3,600 acres of intensive forest management; and 900 acres of lower elevation enclosure that serves as winter range for deer and elk.

Research at Starkey incorporates most forms of recreation typical of National Forests during the spring, summer, and fall. Hunting, for example, plays a key role in the studies. Not only do hunters provide scientists with animal parts necessary to generate data, but they also realistically simulate hunting conditions on other National Forests. Hunting is by permit from the Oregon Department of Fish and Wildlife.

Key issues addressed

The Starkey project has four main studies: intensive forest management, animal unit equivalencies, roads and traffic, and breeding. The intensive forest management study looks at the response of elk, deer, and cattle to intensive timber management. From 1988 to 1998, 3,600 acres will be used to simulate the intensively managed National Forest of the 21st century. Research will focus on the response of the animals to habitat changes from timber harvesting, road building, forest renovation, and other management activities.

The Starkey Project takes place in a 25,000-acre enclosure. Here, steel gates link the fence together at major stream crossings. The gates swing open to allow ice and winter debris to move downstream, which prevents the fence from being pushed over.

In 1988 and 1989, researchers collected baseline information on 50 elk, 50 deer, and 50 cattle fenced inside the timber management area. By June 1990, 30 animals (10 elk, 10 deer, and 10 cattle) will wear radio collars compatible with an automated animal tracking system.

The 3-year, second phase of the study will monitor timber-sale activities such as timber harvest, road work, site preparation, and seedling planting. Then for 3 years after the sale is completed, researchers will measure animal responses to the new forest structure. These final data will be compared with animal use of habitat during the presale and the 3-year harvest, and the road-building phase.

The animal unit equivalency study takes a discerning look at traditional forage allocation on range, which assumes direct competition among elk, deer, and cattle for available resources. Under the traditional assumption, allocation of forage is determined by the weight ratio among the three species. Thus, for every cow-calf pair, or every animal unit that the range can support, the equivalent weight of 2.5 elk or 6 deer could be supported in its place.

The animal units study is designed to increase the accuracy of animal unit equivalencies among the three species by monitoring the animals' use of available habitat. Through observation, researchers know that elk, deer, and cattle do not eat the same plants, in the same proportions, at the same time, or in the same places. Often, deer and elk use steeper slopes, venture farther from water, and eat a wider variety of plants than do cattle. The equivalencies, synthesized into working models, will allow range managers to realistically allocate animal units among elk, deer, and cattle.

In this study, a group of 800 cow-calf pairs will graze in several pastures on a rotating schedule. At the same time, movements of cattle, deer, and elk will be documented with the automated tracking system. The animal locations, plotted on maps and analyzed, will determine how the animals move in response to the presence of the other species.

The roads and traffic study is designed to help managers better understand how elk, deer, and cattle respond to vehicle travel on forest roads, a significant activity on most managed forests today. Although research indicates an inverse relation between the density of roads open to motorized travel and elk use of adjacent habitat, no research has been done to investigate the effects of traffic density and vehicle type on the three species.


More than 60 traffic counters monitor the frequency of vehicles on roads in the Starkey Experimental Forest and Range.

Since fall 1988, rates and types of traffic on roads at Starkey have been monitored along with the distribution of elk, deer, and cattle. Starting in 1992, researchers will build and test traffic pattern models with data gathered at Starkey over the previous three years. Further monitoring and analyses will describe how, or if, the animals are reacting to various traffic patterns and conditions. The results may have an important bearing on future road management schemes in National Forests.

The study on efficiency of breeding bulls examines the relations among age of breeding bull elk, reproductive success, survival of elk calves, and herd productivity. Results from the study will provide key information about managing elk herds to obtain desired productivity levels. Future management decisions may include the redesigning of hunting regulations, which involves millions of dollars in recreation revenues, while creating better hunting conditions and healthier elk herds.

In 1989, the first year of the study, yearling, spike-antlered bulls were the primary breeders. For the next 4 years, these young bulls will be monitored as the primary breeders in the study population. The study may be repeated from 1994 to 1999. During the study, biologists will monitor conception dates, pregnancy and calving rates, and overall health of the herd as the bulls grow older. Findings will determine if, when, and how the age of breeding bull elk affects herd numbers.

Previous studies indicate that yearling bulls may not be as successful as their mature counterparts when breeding. There are many possible reasons that could contribute to low pregnancy and survival rates; for example, yearling bulls often come into rut later in the year, thereby, resulting in later spring calving. Deprived of rich spring nutrients, calves and cows have less time to put on the necessary growth and fat reserves to prepare for winter, which lessens their chances for survival and reproductive opportunities.

New technologies support the studies

An exciting offshoot of the studies is the innovative technologies being used and designed for collecting data. Of the new technologies from Starkey, the first was an 8-foot-high deer- and elk-proof fence built in 1987. The fencing, imported from New Zealand where it is used by commercial red deer ranchers, contains ungulates with minimal injury and low maintenance costs.

The woven wire fencing is exceptionally strong—12 gauge and 170,000 pounds of tensile strength—yet flexible enough to withstand impact if an animal collides with it. Horizontally and vertically woven strands allow the fencing to move and bend on impact. The fence acts like a tight net, rebounding the animals with low risk of injury if they run into it.

Silviculturist Jim Barrett, Wallowa-Whitman National Forest, inventories trees as he designs a timber sale as part of a study to understand how elk, deer, and cattle respond to changes in habitat from timber management activities.

A strand of electric wire at ground level discourages animals from crawling underneath the fence. The entire structure is securely anchored with alternating wood and steel posts sunk 3 feet into the ground at 12-foot intervals. The Starkey fence is expected to stand for 30 years.

Although the fence contains animals under most terrain conditions, six major stream crossings posed a unique challenge to engineers. A series of steel gates that link the fence together at stream crossings were designed and constructed by Forest Service engineers Dave Dahlstrom and Larry Monical, Wallowa-Whitman National Forest. The gates, called ice racks, function like a fence to keep animals inside the study area, but swing open to allow ice and debris to move downstream. Without these gates, winter debris would build up against the fence and eventually push it over.

To monitor the animals within the enclosure, researchers needed a highly sophisticated animal tracking system. Larry Bryant, wildlife biologist at the Pacific Northwest Research Station in La Grande, while searching for an accurate, cost-effective and fast way to track animal movements, hit upon the Loran-C navigation system—the same system used by ships and

aircraft for navigation. With the help of Bryant and Tracor Corp. of Austin, Texas, Loran-C technology was adapted for use at Starkey. By June, 1990, radio collars compatible with Loran-C will be attached to 180 animals—60 deer, 60 elk, and 60 cattle.

The automated tracking system begins and ends with a computer, thereby requiring less fieldwork from biologists. The set-up at Starkey has five radio towers averaging 150 feet in height, two base station computer systems linked to Loran-C hardware, and 180 collared animals. To locate a specific animal, a computer at the base station sends a signal to the base station transmitter. The transmitter sends a high-frequency radio signal to a pager housed in the animal's radio collar. The pager activates the receiver, which starts collecting Loran signals from Loran transmitters in Washington, Nevada, and California. The transmitter inside the animal's collar sends the signals over a microwave link to one of the Starkey field station towers, which retransmits the position back to the Loran-C hardware at the base station to compute the location. Locations are stored on magnetic disc inside the computer and can be displayed on an interactive computerized map. Data from the disc are entered into a database and stored on magnetic tape.

The Loran-C system can compute one animal location every 15 seconds and is accurate to within 50 meters. In the 10 years of study, the system is expected to generate more than four million locations—over 100 times more locations than most conventional tracking methods can compute.

Another innovation at Starkey is a winter feed and handling facility. Several forest management issues relate to winter range. More than 90 percent of all elk summer range in the United States, however, is on National Forests. The research underway at Starkey is designed for summer range only with winter used as a control period.

As temperatures begin to drop and snow accumulates, elk and deer herds are baited to a 900-acre area with alfalfa hay and pellets. Once there, feeding rates are adjusted to simulate the experience of an average eastern Oregon winter so that animals reenter the summer range in the same condition each spring. Differences in population and reproduction responses, therefore, can be attributed to the changing summer habitat conditions and not the variable effects of winter.

At the handling facility; researchers are able to gather essential information about elk population and physiological responses to the experiments. Elk are handled at a specially designed series of pens and chutes where they can be checked for disease and pregnancy status and be equipped with radio collars. Because deer become stressed when subjected to pens and chutes, they are trapped and handled individually to reduce injury.

In another aspect of the Starkey Project, vehicle travel on roads is monitored. Information is collected at 70 different sites with traffic counters along more than 270 miles of road throughout the enclosure. Two of the counters have small cameras (deliberately set out of focus so that the driver and license plates cannot be identified to assure driver privacy).

After the film from these cameras is developed, the vehicles will be classified, for example, as recreational, administrative, or large truck. Traffic data will be transferred to a database and analyzed along with animal locations and other habitat features.

Although some of the technologies at Starkey are still in the developmental stage, data are already being generated at a fast pace. To manage the mounting piles of data, computer specialists adapted Geographic Information Systems (GIS) to collect, sort, and process animal locations and habitat information. With GIS, researchers will be able to produce tables, maps, graphs, and text to help managers make decisions about forest use.

Because of hunting pressures, yearling, spike-antlered bull elk are becoming the dominant breeders in many herds.

Using the GIS, location data are analyzed in relation to habitat conditions by dividing the entire study area into a series of grid cells. The average cell size is about one square acre each, and there are about 540,000 cells. Locations generated with the automated tracking system will be placed in the cells and analyzed in relation to more than 80 habitat features, such as slope, aspect, elevation, canopy closure, and distance to water and roads.

Technology transfer

The Starkey project is one of the most highly publicized research projects ever conducted by the Oregon Department of Fish and Wildlife and the Forest Service. The high economic stakes associated with the application of research results has created an increasing demand for information by many audiences. That need led to the development of an active technology transfer program. The program strives to link researchers, forest users, and managers with research results in understandable, usable, and readily available forms. Some study results may be available in three years. The results will be packaged in various ways: tours, presentations, workshops, and handbooks. Also, a series of PNW research notes is being written on the technologies used in the Starkey project.

Primary scientists with the Starkey Project include Jack Ward Thomas, Project Leader, and Larry Bryant and Mike Wisdom, Wildlife Biologists, Forest Service; and Jim Noyes and Leonard Erickson, Wildlife Biologists, Oregon Department of Fish and Wildlife. For more information about the project, contact Mike Wisdom at the Forestry and Range Sciences Laboratory, 1401 Gekeler Lane, La Grande, OR, 97850 (503/963-7122).

Riparian ecosystems: jewels in the Southwest

by Rick Fletcher
Rocky Mountain Station

Healthy riparian ecosystems exist under a delicate environmental balance.

Riparian areas are ecologically important habitats throughout the Southwest. They are found in two distinctly different environments—along small high-elevation streams, and along large downstream rivers which pass through the hot deserts.

Riparian ecosystems are home to wildlife, offer recreational opportunities, provide storage for sediment, serve as nutrient sinks for surrounding watersheds, and improve the quality of water leaving the watershed. They also help control water temperatures through shading, reduce flood peaks, and serve as key recharge points for renewing ground water supplies.

A healthy riparian ecosystem is in dynamic equilibrium with the stream. In this condition, the riparian vegetation remains vigorous and does not encroach into the channel, nor does streamflow expand into the vegetation area, or impact the channel bed. The attributes of healthy and unhealthy riparian areas are given in Table 1.

Throughout much of the Southwest, healthy riparian ecosystems are often more the exception than the rule. In many higher-elevation forested areas, grazing, timber harvesting, and other activities have compacted the soil and reduced protective plant cover.

These impacts have reduced infiltration and increased overland flow, and resulted in channel enlargement and downcutting. At lower elevations, woodcutting, agricultural development, urbanization, and overpumping of groundwater aquifers are responsible for the wide-spread destruction of riparian areas. But, although they are sensitive to disturbance and degradation, they are also resilient and can recover rapidly when managed properly.

Finding answers

Scientists with the Rocky Mountain Station's Forestry Sciences Laboratory in Tempe, Arizona, have been studying ways of managing and restoring southwestern watersheds and associated riparian areas for many years. Their research has resulted in several technical reports for land managers—the latest being a state-of-the-art publication titled "Improving Southwestern Riparian Areas Through Watershed Management". Co-author and Supervisory Soil Scientist Leonard DeBano, who heads the Station's Management of Southwestern Watersheds project, says, "Our studies have focused on two approaches for improving riparian areas—enhancement and rehabilitation. Enhancement means returning the riparian/stream habitat to a more productive condition by natural or artificial means. This includes those activities that change streamflow regimes to encourage the establishment of new riparian areas. Rehabilitation describes those situations where deteriorated riparian areas are improved, but may not necessarily be restored to pristine conditions."

"Improving riparian areas requires (1) realizing there is a balance between riparian health and upslope watershed condition; (2) correctly diagnosing causes for any unbalance; and (3) implementing appropriate rehabilitation treatment plans," says DeBano. "The balance between watershed condition and riparian health is delicate—it responds readily to both natural processes and human activities."

A variety of land treatments have been applied to deteriorated watersheds to help stabilize or create downstream riparian ecosystems. They are based on two general types of action programs: (1) improving watershed condition on the sideslopes, and (2) stabilizing channels to reduce erosion and downcutting.

DeBano points out that these programs provide a basis for defining and implementing treatments ranging from simple changes in grazing management, timber harvesting practices, or planting and revegetation activities, to more complex measures involving construction of channel structures or mechanical sideslope treatments.

Watershed condition

Research results point out that a first, and essential, step in restoring riparian health is to improve watershed condition. Riparian rehabilitation should not be attempted in stream systems where upslope watershed condition is unsatisfactory or in a downward trend.

DeBano says, "On rangelands, the simplest way of improving watershed condition is to provide plants an opportunity to regain vigor and establish a denser ground cover through proper grazing management. Increasing plant cover allows more water to infiltrate the soil mantle, where it slowly moves downslope through the soil until it reappears as channel flow. Where plant cover cannot be improved by grazing management alone, grass seeding and mechanical treatments may be necessary.

	Healthy		Unhealthy
A	Efficient channel shape with narrow channel that conveys all flows less than that of the mean annual flood (2.33-year recurrence interval) with minimal bank and channel erosion.	A′	Inefficient channel shape often braided or shallow and widely fluctuating. Most flows confined in channel. Severe bank and channel erosion and expanding width.
B	Stream power < critical power.	B′	Stream power > critical power.
C	Channels have low hydraulic energy gradient and high sinuosity.	C′	Channels have high hydraulic energy gradient and low sinuosity.
D	Flows above mean annual flood leading to low energy flow on the floodplain: dissipating energy, filtering sediment, and capturing sediment.	D′	Flows above mean annual flood lead to high velocity on the floodplain. Limited energy dissipation. Removal of sediment and nutrients from floodplain.
E	Log step and transverse gravel bar formation in confined channels. Infrequent occurrence of knickpoints. Well-developed meanders in nonconfined channel.	E′	Channel steps are lacking. Frequent occurrence of knickpoints.
F	Channel generally stable with aggrading floodplain.	F′	Channel degrading with mildly infrequent floodplain deposits. Floodplains undermined and eroded.
G	Water table near surface and increased water storage capacity.	G′	Deep water table and decreased water storage capacity.
H	Abundant vegetation with roots penetrating and stabilizing nearby streambanks.	H′	Little vegetation and roots to protect and stabilize streambanks.
I	Larger late summer streamflows.	I′	Low late summer streamflows.

Important attributes of healthy and unhealthy riparian areas.

Forested and chaparral areas require different techniques from those used for rangelands. They will depend, in part, on the degree of disturbance. Timber and fuelwood harvesting are most frequently responsible for degrading watershed condition on forested lands. Minimizing soil disturbance and compaction during logging, along with proper road design and location, are important considerations during timber harvesting. Chaparral watersheds are affected primarily by brush-to-grass conversions or by wild and prescribed fires.

Watershed treatment

After the factors responsible for disrupting the balance between watershed condition and riparian health have been identified, their causes can be used to formulate specific treatment objectives and remedies (Table 2). The large array of possible treatment alternatives can be classified into four broad coarses of action. One alternative is to do nothing. This is often not acceptable to managers where riparian/watershed systems are out of balance. A second alternative may involve only managing, or treating sideslopes. Sideslope treatment can be feasible on watersheds where naturally occurring channel controls, such as bedrock, are present. Bedrock usually limits downcutting and thereby eliminates any need to stabilize the channels. Under this alternative, if rilling and gullying have not occurred, then sideslope management alone may allow a dense vegetative cover to become established. Where surface rilling and incipient gullying are severe, channel shaping, contour trenching, and revegetation may be required.

A third, more complex, alternative involves channel stablization. This alternative should be attempted only where watersheds are healing naturally as a result of improved management. The objective of this treatment could be to stabilize or stop downcutting, reduce erosion, and revegetate channel banks. Channel structures, such as check dams, could be constructed to control base levels. Dam spacing and effective spillway heights can be designed to store enough sediment to stabilize the channel, which in turn aids in stabilizing adjoining sideslopes.

Finally, the fourth and most comprehensive treatment alternative involves both channel stabilization and comprehensive watershed rehabilitation. The objective of this level of treatment would be to stabilize and aggrade channels, and provide adequate water storage to encourage the establishment of riparian ecosystems. Channel deposition and ground water recharge could be enhanced by increasing dam spacing and spillway heights. The resulting channel aggradation would provide water storage behind each structure, and improve soil moisture and channel flow. Riparian establishment could occur naturally or be enhanced by planting species adapted to the area.

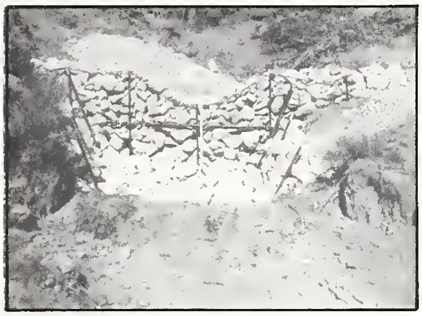
"Any combination of the last three levels of action plans may be implemented within a single watershed, but it remains critical to establish treatment objectives first," says DeBano. "Although it is possible to enhance or rehabilitate potential riparian areas with these treatments, I emphasize the importance of continual management and maintenance as an integral part of these rehabilitation plans in order to maintain the effectiveness of the initial treatments," he said.

"In all cases," says DeBano, "the land manager must recognize that long periods of time may pass before changes in watershed sideslopes are manifest in the channels and associated riparian ecosystems, or vice versa."

Water augmentation

Because water is a scarce resource throughout the Southwest, increasing streamflow by vegetation manipulation has been a high priority issue for many years. As a result, studies have assessed potential water augmentations by cover manipulation, both in riparian areas and on surrounding watersheds.

Some of this earlier research indicated that removing "phreatophyte" vegetation (deep-rooted plants that transpire lots of water) occupying riparian areas, both along the larger rivers passing through the desert and on small upland riparian areas, could potentially increase streamflow for other uses. However, the growing concern for riparian areas as a source of diverse products and



An upstream view of a rock check dam constructed in an upper watershed channel on Alkali Creek in western Colorado: immediately after construction in 1963 (left), in 1964 (middle), and 12 years later in 1975. Notice the establishment of grass on channel banks and bottoms.

amenity values has discouraged managing these areas solely for "phreatophyte control" and producing more water.

Would downstream riparian communities use up much of the increased water produced as a result of timber harvesting and shrub control? Studies indicate the greatest potential increase in streamflow per acre can be realized in mixed conifer, because this vegetation type receives the greatest amount of annual precipitation. In this forest type, water yield increases occur mainly during spring when water use by riparian plants is lowest, so that the impact of riparian areas on increased streamflow is minimized.

Other studies have shown that increased streamflow in response to tree removal in ponderosa pine forests and pinyon-juniper woodlands is relatively small, and is unlikely to enhance riparian ecosystems in these forest types.

"Over the years", says DeBano, "we have found that brush-to-grass conversion in Arizona chaparral is perhaps the most promising management tool for enhancing riparian areas, because it not only produces the second largest increase in water yield per acre treated, following mixed conifer, but also increases streamflow duration significantly. The increased water yields in chaparral also occur mainly during the winter and spring when water use by riparian vegetation is lowest. Brush-to-grass conversions also reduce fire hazard and increase wildlife habitat diversity," he said.

Stabilizing channel networks

DeBano points out that improved grazing methods and vegetation manipulation measures alone may not be sufficient to fully restore former riparian areas—especially if extensive gullying has dissected ground water tables and caused a general dewatering of the area.

"When incised channels are present, additional supplementary measures may be needed," he says. "These may include construction of gully structures in upland watersheds, or channel modification in riparian areas to restore water tables and create stream types with characteristics more desirable for riparian ecosystems."

Man-made structures

Dams are one of the oldest and most common physical structures used for regulating streamflow. Because of their effect on streamflow and sediment transport, large water storage and flood control dams can dramatically influence both upstream and downstream channels and associated riparian ecosystems.

Condition	Cause	Remedy	Treatment objective
Excess runoff	Major flood events on pristine watersheds.	None on watershed. If riparian areas have been damaged, then some structures, bank stabilization, and revegetation may be necessary.	Rehabilitate changes.
	Areas with depleted cover lacking infiltration capacity and resistance to surface runoff.	Improve livestock, game, or fire management. Revegetate and manage for increased vegetation and litter cover.	Increase resistance to surface flow. Greater infiltration capacity. Eliminate sheet runoff.
Increased frequency and magnitude of flow events.	Rilled and gullied slopes resulting from depleted cover or soil compaction.	Reduce drainage density by constructing contour furrows or trenches and manage for increased ground cover. Restoration of vegetation.	Increase retention of storm flow on-site until infiltrated. Eliminate concentrated flow. Regulate runoff through soil mantle. Increase vegetation cover and improve infiltration.
	Roads and travelways that intercept, collect, and concentrate flows.	Intercept flow paths with waterbar and divert flows to areas with greater infiltration capacity. Rip and reseed compacted surfaces where travelways have been abandoned. Improve forest filter by adding log flow obstructions or detention basins. Eliminate traffic.	Shorten slope length. Infiltrate excess flow into forest floor. Restore on-site infiltration of flow and protect soil. Regulate flows through soil mantle.
Excess discharge	Transbasin diversion that produces the effect of greater drainage area and increased flow.	Provide reservoir storage to regulate transferred flows. Avoid inchannel transport of increased flows. Convey increased flows during low-stage seasons.	Maintain flows within the limits of critical stream power.
	Forest harvest effects on water yield that produce greater runoff.	Schedule harvests in time and space over the watershed to maintain increased runoff within the range of channel capacity and critical power. Consider effects of various silviculture techniques on snow retention and water yield. Minimize road density and drainage of lower slopes by roads.	Maintain flows within critical power threshold. Dissipate peak flows through soil mantle.

Conditions threatening riparian areas and possible remedies for achieving different treatment objectives (con't).

Condition	Cause	Remedy	Treatment objective
Excess stream slope	Channelization of riparian areas by roads, trails, and travelways.	Avoid roads, trails, and travelways in riparian areas. Eliminate old travelways and relocate where necessary. Take special precautions and measures to avoid channelized flow where facilities must be in riparian areas.	Maintain slope, channel length, and configuration that support dynamic equilibrium. Avoid actions that concentrate flows, produce higher velocities, or change energy configuration of channels or meadows.
	Historic channelized riparian caused by arroyos, gullies, and travelways.	Reestablish and construct channel configuration and slope that watershed conditions can sustain (Heede 1968a) or use check dams to control grade while channel adjusts to new equilibrium. Where conditions allow, consider introducing beaver.	Develop slope channel length and configuration that supports a new dynamic equilibrium. Correct conditions that generate unfavorable flows.
	Absence of large organic debris to provide steps and energy dissipation in confined mountain channels.	Add logs or rock structures to regain stability. Manage adjacent areas to provide a desired rate of logs to the system.	Reduce streamslope with log steps or other structures. Slow velocities, reduce flood peaks, and increase channel uptake. Stabilize sediments.
Excess tributary sediment	Sheet and rill erosion from denuded areas.	Apply techniques similar to those used for controlling excess runoff.	Reduce exposure to erosion. Eliminate concentrated flow on slopes. Provide vegetation protection.
Excess bank sediment	Incised, confined channels that cut high banks.	Improve watershed condition. Reduce bank heights by installing check dams. Use flow separation techniques to deposit materials to buttress banks and provide a media for riparian vegetation establishment. Use techniques outlined for excess slope.	Reduce availability of sediment. Restore channel equilibrium that can be sustained.

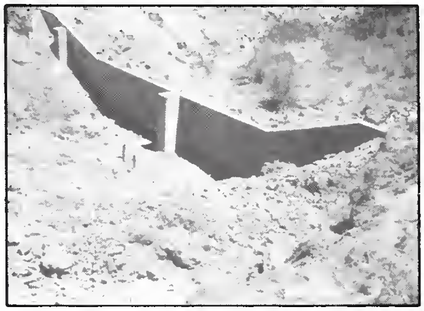
Reservoirs accumulate sediment both at the dam site and in the delta where the stream enters the reservoir. As a result, local base levels of the stream rise, causing aggradation in the lower stream reaches. Where bank materials are erodible, this aggradation leads to channel widening and provides excellent habitat for riparian plants.

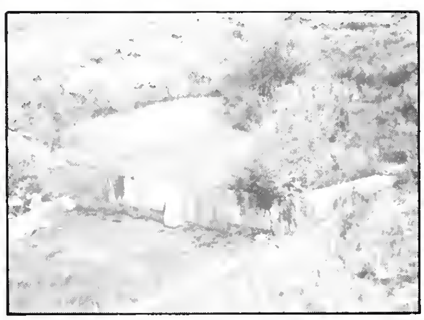
Intermediate-sized in-stream structures

Structures of intermediate size, such as weirs, commonly used for stabilizing channel downcutting and degradation, can stabilize stream reaches, store sediment, and enhance establishment of riparian ecosystems. The structures vary in size, but are larger than the channel checks used in small gully networks. Although multiple structures in a channel are usually the most effective for riparian enhancement, single structures, particularly if combined with upstream cover manipulations, may serve equally well.

Bank protection structures

Bank protection structures can be grouped into armoring banks, deflecting flows, and separating flows. Armors are designed to keep banks in their present location; deflectors are used for eliminating flow impacts on critical banks; separators divide flow into high- and low-energy segments. All three types can protect and enhance riparian plant communities if correctly designed.





A large gully control structure at the mouth of Alkali Creek in western Colorado: immediately after installation in 1963 (top), in 1964 (middle), and 12 years later in 1975.

Bank armor usually consists of various kinds of riprap, revetments, gabions, and a variety of other structures installed parallel to a bank, and can be constructed according to several designs.

Flow deflectors are frequently used for protecting banks and areas adjacent to the channel from the stream's impact. These deflectors can be used to save endangered riparian plant communities.

Flow separation structures are designed to create low-energy flows along banks. They usually consist of woven wire fences or jack/tetrahedron fields installed at some distance from the bank.

Natural structures

Several types of channel structures created by naturally occurring processes can create environments favoring riparian ecosystems. The most important are cienegas (marshlands), log steps in small streams, debris accumulation in large streams, and beaver dams.

Under natural conditions, cienegas evolve after the soils in an area have passed through a series of aggradation and degradation steps following channel obstruction. Very active first- and second-order tributaries may deposit coarse material as alluvial fans, and obstruct channels in higher order, steep-walled drainages. These alluvial fans act as channel controls, reducing slope gradients and encouraging deposition of materials. Subsequent ponding of alluvial ground water and trapping of sediment initiates riparian plant establishment and succession.

Vegetation establishment on the cienegas, combined with their relatively flat topography, effectively dissipates energy and fosters sediment and organic matter deposition which, in turn, improves infiltration of water. Over time, a diverse riparian ecosystem becomes established.

Forest and riparian plant communities along small streams act as both erosion buffer strips and nutrient filters. This occurs when trees and logs fall across the channel and are incorporated into the hydraulic geometry of the stream channel, creating log steps. When this organic debris accumulates on the streambanks, it improves channel stability by promoting soil development, increasing infiltration, and reducing overland flow and bank erosion. The log steps in the stream channel accumulate sediment, thereby reducing the channel gradient and improving channel stability. Waterfalls then develop over each step which further reduce flow energies.

Large organic debris in channels also play an important role in maintaining riparian ecosystems along the larger, low-elevation rivers of the Southwest. In this desert stream environment, accumulations function as sources of nutrients and also provide a quasi-stable environment in an otherwise often unstable system.

Beaver dams also create favorable channel environments for riparian ecosystems. These dams usually extend fully across a channel and act as a very wide weir during flood peaks, affecting the hydraulic regime in at least two ways. First, flood waters are spread over a wider area, which reduces the hydraulic head. This reduces highly turbulent waters into a more tranquil flow, and decreases the erosional energy of flowing water. Secondly, peak discharges during runoff events may be dissipated, because these dams have some water retention capacity.

Beaver dams need special consideration because they are built according to different engineering standards than man-made structures, and are dependent upon stable beaver populations. Beaver dams can often be introduced or reestablished where adequate food sources are available.

More answers needed

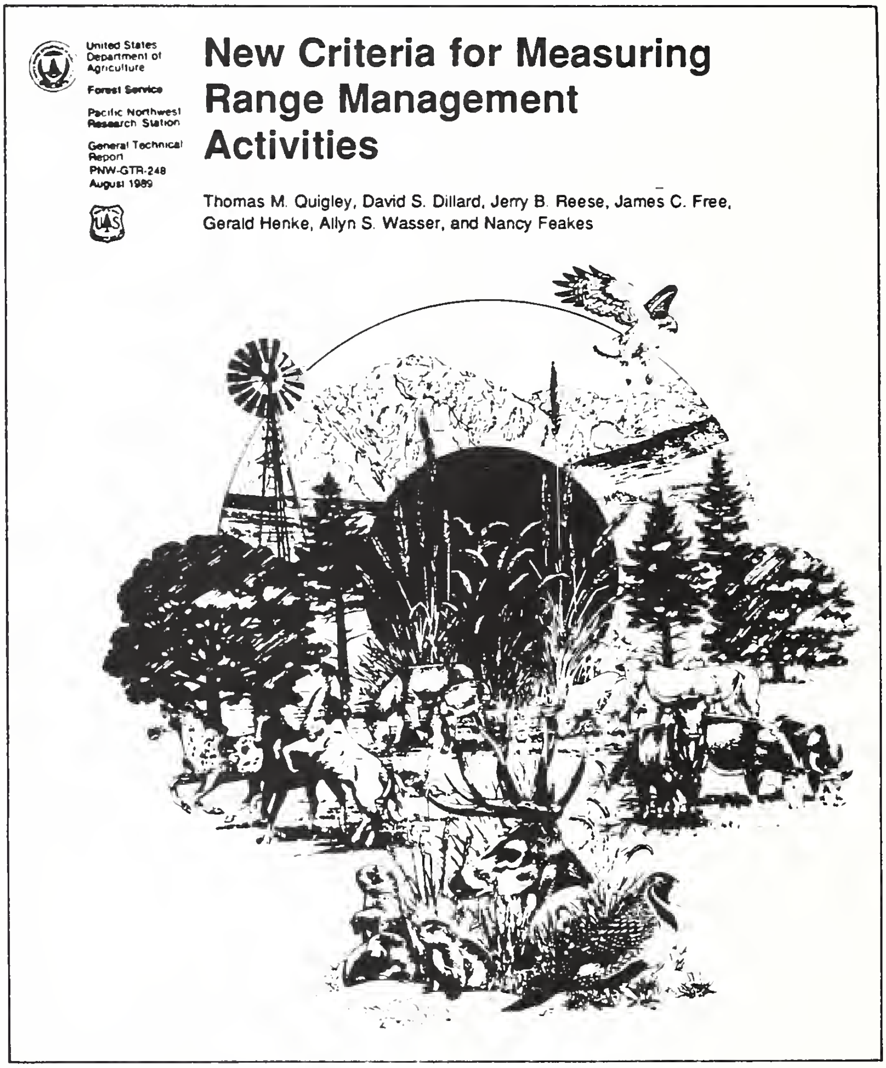
Although much has been learned from recent studies, research continues on several fronts. Scientists are still working to answer such questions as: (1) what are the specific sequences of treatments needed for establishing an acceptable balance between watershed condition and riparian health as related to different management objectives; (2) what is the role of sideslope vegetation on channel processes, and the role of riparian communities on nutrient dynamics, sediment transport, and contaminant capture in associated streams; and (3) what is the dynamic exchange of water between surface and ground water sources?

Management of riparian areas is a critical issue in the southwestern United States. These research results should help resource specialists establish, improve, and maintain riparian areas, and better understand the tradeoffs required among various uses, including recreation, wildlife and fisheries habitat, grazing, and water yield augmentation.

For a more in-depth look at improving southwestern riparian areas, write the Rocky Mountain Station and request *Improving Southwestern Riparian Areas Through Watershed Management*, General Technical Report RM-182. Readers can also contact Leonard DeBano at: Rocky Mountain Forest and Range Experiment Station, Forestry Sciences Laboratory, Arizona State University, Tempe, Arizona 85287-1304; phone (602) 379-4365, FTS - 261-4365.

New from research

A broader view of range



United States Department of Agriculture

Forest Service

Pacific Northwest Research Station

General Technical Report PNW-GTR-248 August 1989

New Criteria for Measuring Range Management Activities

Thomas M. Quigley, David S. Dillard, Jerry B. Reese, James C. Free, Gerald Henke, Allyn S. Wasser, and Nancy Feakes

Range is complex with a diversity of plants and animals—domestic and wild—to be held in balance. When range is damaged, restoration can take decades. Measures for describing range and its management, traditionally, have not reflected the length of time needed for improvement or the many values of rangelands.

This publication lists the recommendations of a Forest Service task force assigned to reexamine the measurement of range. The seven authors provide measurement tools that broaden the emphasis to include grazing and increased emphasis on vegetation management. Five broad areas of measurement are proposed: range vegetation management, riparian vegetation management, grazing management, noxious weed management, and wild horse and burro management. For each area, the authors provide definitions, background, descriptions of management, and the proposed measures and their rationale. For a copy, request *New Criteria for Measuring Range Management Activities*, General Technical Report PNW-248.

Economics and risk on fire management programs

In a time where forest budgets are strained and funding for fire is tight, current research is helping fire managers to better understand the economic effects of fire management programs.

Because of the fire system's highly stochastic and complex nature, there is relatively little information on the economic efficiency of alternative fire management programs and even less on the tradeoffs between efficiency and risk.

Pacific Southwest Station scientists have set out to address these concerns. As a result they formulated three hypotheses about fire system performance to guide analysis into these dimensions: 1) Economic efficiency; 2) Risk in the fire management system; and 3) Efficient funding level.

For more information order *The Economic Efficiency and Risk Character of Fire Management Programs, Northern Rocky Mountains*, Research Paper PSW-192, available from the Pacific Southwest Station.

Carefully select stands and parent trees to fight gall rust

Because susceptibility to western gall rust appears random, you must carefully examine potential stands and trees for ponderosa pine regeneration, Geneticist R.J. Hoff learned from a study within the middle Columbia River drainage in Montana, Idaho, and Washington.

Earlier research showed that this region's ponderosa is generally more resistant to the disease than the same species in the Southern Rockies and Colorado plains. However, some stands or trees may be highly susceptible to the disease within the middle Columbia region where trees are generally resistant. Whether selecting trees for natural regeneration or seed, trees should be carefully examined to make sure they are not susceptible variants.

The research showed only moderate rust association with elevation and geographic area.

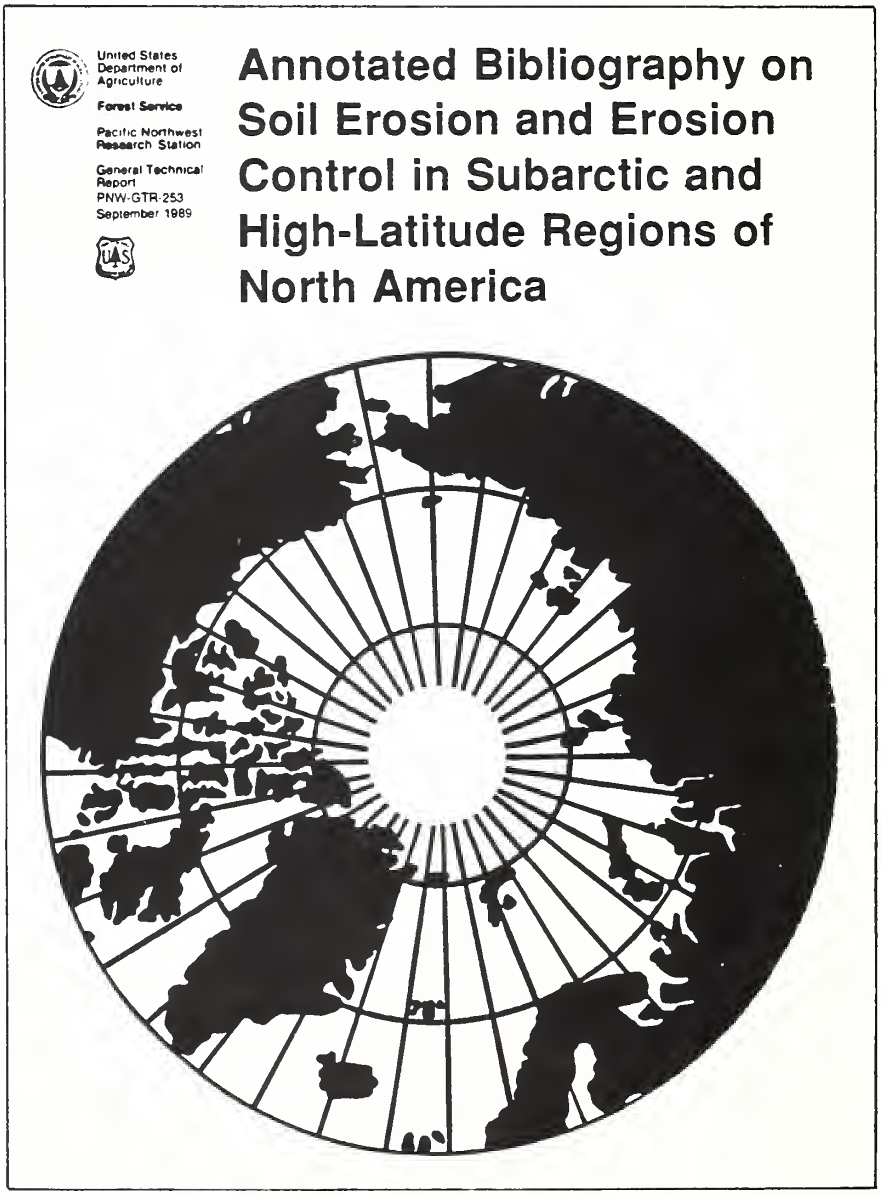
Request *Susceptibility of Ponderosa Pine to Western Gall Rust Within the Middle Columbia River System*, Research Paper INT-416, available from the Intermountain Station.

Erosion bibliography for the subarctic and high latitudes

Recent, planned, and potential development in subarctic and Arctic Alaska may lead to unnecessary soil erosion, site deterioration, and degradation of water quality. This bibliography provides land managers and construction personnel with information about scientific literature on soil erosion and erosion-control principles and practices for these regions.

The literature review confirms that, for these regions, the basic processes of soil erosion are understood, and the techniques for controlling erosion are well documented. Procedures for making gross estimates of soil erosion from disturbed and undisturbed lands are now available, as are procedures for predicting sediment deposition and yield.

In this review, each literature citation has an annotation that usually is quoted from the author's abstract or summary. Information relevant to the literature review but not included in the author's abstract is also sometimes added. The bibliography emphasizes the physical processes of upland soil erosion, prediction of soil erosion and sediment yield, and erosion control. The literature reviewed is mostly from the United States and Canada. Most of the cited works were published before 1981. For a copy, request *Annotated Bibliography on Soil Erosion and Erosion Control in Subarctic and High-Latitude Regions of North America*, General Technical Report PNW-253.



Linear programming introduced to help forest planners

A recent report helps explain the basic concepts of linear programming (LP) to forest planners and others who must use the technique to develop national forest land management plans. The role of LP in national forest planning analysis is also presented.

Needed basic algebraic concepts are reviewed, and various components of an LP model are described, as are its advantages and limitations. Examples are presented to illustrate how the technique can be used to formulate forest planning models, and how it is used in the Forest Service land management planning process. Procedures for solving LP models and the technique known as "goal programming" are also discussed. No prior background in LP is required of the reader.

For your copy, request *Forest Service Land Management Planners' Introduction to Linear Programming*, General Technical Report RM-173, available from the Rocky Mountain Station.

The use of volume tables for timber inventory

Intensive forestry requires that foresters be able to estimate tree volume accurately for such phases of timber management as timber sales, forest surveys, appraisals for land exchanges, evaluations of damage, advance planning, and growth and yield studies.

To be of value, estimates of tree volume should be expressed in units of measure that relate to the products derived from the tree, and that are expressed in terms familiar to the user.

A new research note explains the use and benefits of using volume tables to display important data critical in the management of any timber stand. For your copy, write the Pacific Southwest Station and request *Local Volume Tables for Young-Growth Conifers on a High Quality Site in the Northern Sierra Nevada*, Research Note PSW-404.

Fish trap for measuring fish on the move

Fishery scientists and managers study downstream fish migration to project future returns of adults, assess land-use effects on fish, and evaluate habitat restoration and enhancement. Different types of nets and traps have been used to collect information on downstream movement with only partial success. This publication describes a floating, self-cleaning downstream migrant trap that is successful at trapping chinook and coho salmon, steelhead trout, and other fishes.

The modified Humphreys trap functions effectively for several streamflow ranges and handles small floating debris while staying efficient. The trap is inexpensive, light weight, easy to reposition, and results in low mortality of fish captured. Because the trap samples only a portion of the fish moving downstream, it requires calibration of the capture efficiency and flow levels for calculating estimates of the total number of downstream migrants. For a copy, request *A Floating Trap for Sampling Downstream Migrant Fishes*, Research Note PNW-490.

Improving growth of planted lodgepole through judicious seed selection

After 12 years of growth on a site in Montana, lodgepole pine saplings from Idaho and Washington seeds showed greater growth than saplings grown from seed collected nearby in Montana.

These study results from a subalpine site in the Gallatin National Forest challenge the traditional wisdom that seed collected from trees known to be adapted to the site provide the best survival and growth. There was no significant difference in survival between seedlings grown from seed collected in four States. Idaho seed demonstrated a little growth superiority to Washington, while Utah seed grew the shortest trees and local Montana seed demonstrated intermediate potential. Researchers measured height, diameter, and crown width to determine total growth.

The results of this study also help provide insights to the relationship of elevation and latitude, and within-family variation as it relates to seed sources from widely separated geographic regions.

Request *Developmental Differences Among Five Lodgepole Pine Provences Planted on a Subalpine Site in Montana*, Research Paper INT-415, available from the Intermountain Station.

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Research Station

Research Paper
INT-415

November 1989

Developmental Differences Among Five Lodgepole Pine Provenances Planted on a Subalpine Site in Montana

Dennis M. Cole

Piecewise SALT sampling

Forest activities such as logging, road building, and mining can reduce water quality in streams and rivers. Increased sediment delivery is a possible result of such activities. Increased sediment production can have direct effects on sedimentation and fisheries, or indirect effects by acting as a vehicle for chemical pollutants.

Piecewise SALT is a modification of the original SALT procedure. It allows the user to adjust sampling to special needs such as measuring smaller storms and to limit sample collection to logistically possible regimes.

Piecewise SALT also provides estimators for periods essentially disconnected from the times of station visits. Details are described in *Piecewise SALT Sampling for Estimating Suspended Sediment Yields*, General Technical Report PSW-114, available from the Pacific Southwest Station.

Estimating postfire water yield

Wildfire annually burns thousands of acres of Pacific Northwest watersheds and can affect the quantity and quality of water resources. Fire often produces an increase in water yield which may persist for many years.

A new report presents a methodology in which site-specific hydrologic models were adapted to provide the estimates of postfire water yield for fire management planning. The Pacific Southwest Station has copies of *Estimating Postfire Water Production in the Pacific Northwest*, Research Paper PSW-197.

Wildlife damage control discussed

The study of damage caused by animals has become complex and diverse over the years. Because of this, professionals have met annually for the past nine years to discuss ways to control it. In 1989, the workshop was held in Fort Collins, Colorado on April 17–20.

Papers were presented in sessions titled: Overview, Carnivores, Urban, Big Game, Birds, and Rodents and Lagomorphs. Specific papers included topics such as grackle control, managing urban deer, and sheep loss due to mountain lion attacks. The need to consider public attitudes in all phases of planning and implementation was an underlying theme throughout the workshop.

The workshop was sponsored by the Great Plains Agricultural Council, Wildlife Resources Committee. To learn more, request *Ninth Great Plains Wildlife Damage Control Workshop Proceedings*, General Technical Report RM-171, available from the Rocky Mountain Station.

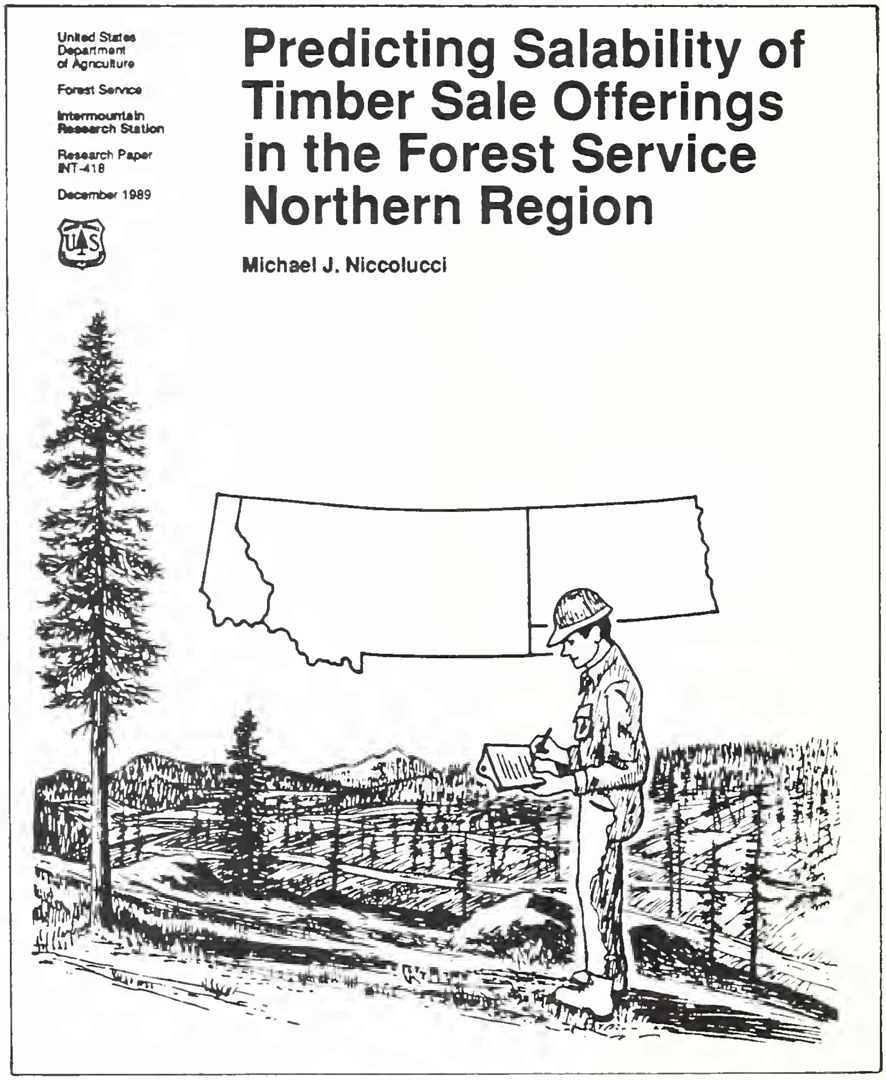
Predicting timber salability: a money-saving tool

Two statistical methods, developed to use with the Forest Service's Northern Region's "Gates" timber planning and decision process, can help managers save money by identifying timber sales with a low probability of sale as early as possible in the planning process. When managers learn that a sale probably won't sell they can modify sale design or eliminate the sale before investing additional time and money.

Economist Michael J. Niccolucci compares the effectiveness of the two methods, and analyzes the potential for prediction in successive stages or "Gates" in the planning process. The methods succeeded more often west of the Continental Divide where fewer variables occur. Salability was correctly classified 59 to 90 percent of the time.

The classification methods as used in the study aren't suitable for use outside the Northern Region.

Request *Predicting Salability of Timber Sale Offerings in the Forest Service Northern Region*, Research Paper INT-418, available from the Intermountain Station.



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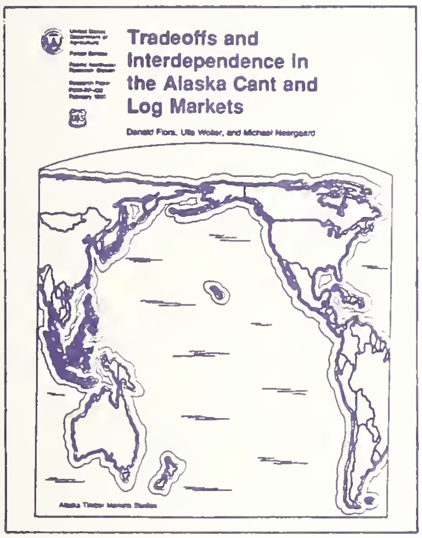
Dynamics in Alaska log and lumber exports



Aggressive timber harvesting on Alaska's private lands has been expected to reduce log exports sharply in the early 1990s. This concept implies, however, a sharp rise in demand for lumber (cants) and other sawn products.

This research paper examines why, during the 1980s, log exports rose while lumber exports declined. The authors explore eight explanations for the difference between lumber and log market behavior. They conclude that a declining demand for wood products in Japan and a surge of private-sector log harvests in Alaska are seemingly enough to account for the apparent substitution of logs for cants. Possibly, for select grades, logs directly displaced lumber in the export market. For a copy, request *Tradeoffs and Interdependence in the Alaska Cant and Log Markets*, Research Paper PNW-422.

Analysis of various resource situations presented

The Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) directs the Secretary of Agriculture to conduct an assessment, every ten years, of the Nation's forest and rangeland resource situations covering all renewable resources within the purview of the Forest Service.

The 1989 assessment, the third prepared in response to the RPA legislation, presents an analyses of present and anticipated uses, demand for, and supply of the renewable resources of forest, range, and other associated lands.

The complete analyses of each of these resources are presented in five technical reports titled: *An Analysis of the Water Situation in the United States: 1989–2040*, General Technical Report RM-177; *An Analysis of the Wildlife and Fish Situation in the United States: 1989–2040*, General Technical Report RM-178; *An Analysis of the Minerals Situation in the United States: 1989–2040*, General Technical Report RM-179; *An Analysis of the Range Forage Situation in the United States: 1989–2040*, General Technical Report RM-180; and *An Analysis of the Land Base Situation in the United States: 1989–2040*, General Technical Report RM-181. Request copies from the Rocky Mountain Station.

Two additional reports, one on timber and one on outdoor recreation and wilderness, are forthcoming and will be announced in a future issue of Forestry Research West.

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